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Theoretical Study of Non-equilibrium Ionization in the Presence of Electric and Magnetic Fields

Progress Report No. 4

for the period August 1, 1964 - February 28, 1965

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During the period August 1, 1964 to February 28, 1965 two publications (References 1 and 2) have appeared. Reference 1 has been revised and will appear as a paper in the AIAA Journal. In addition, a paper[3] will be presented at the Sixth Symposium of the Engineering Aspects of MHD.

Specific Impulse Prediction

A method has been devised which was successful in predicting thrust for Co-axial Hall Current Accelerators. The method was applied to the device discussed in Reference 4 and the results of calculations were compared with the measurements in Reference 5. As is seen from the enclosed figure the agreement is rather good.

The success of the method depends on a suitable estimate of the cathode radius. In the absence of any theory suitable for predicting such a radius, a parametric study of the effect of the cathode radius on the various discharge parameters was undertaken. The cathode radius was found to be a strong function of the magnetic field and an approximate formula describing this dependence was obtained. This formula was then employed in the specific impulse calculation. The enclosed figure is a typical result.

Heat Transfer Estimates

We have finally succeeded in finding a numerical technique suitable for solving the heat transfer problem in Co-axial Hall Current Accelerators. The problem is a two point boundary value problem and was reduced to a system of four differential equations. Because of the

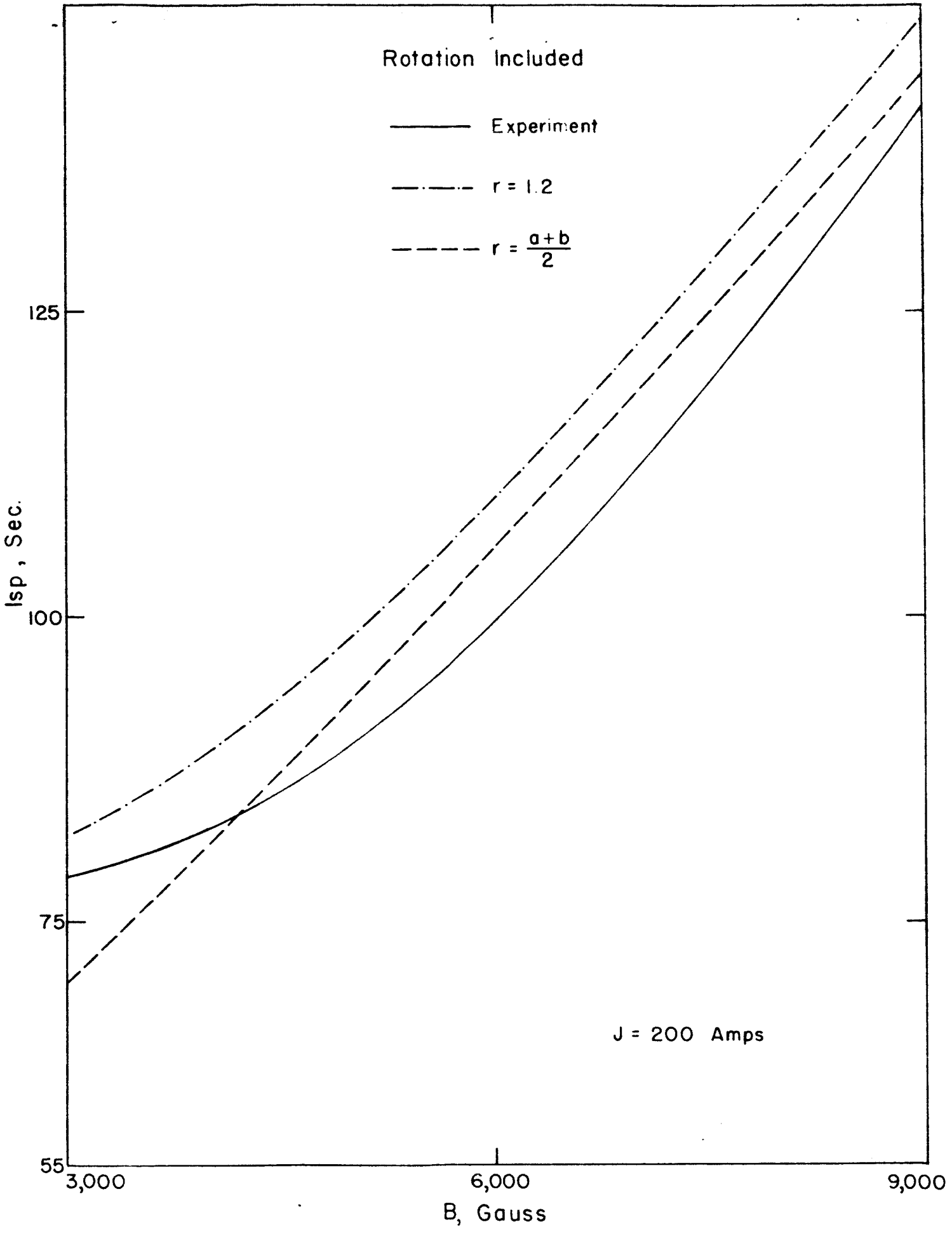
number of equations involved, the usual method of solution is not practical because it requires, in this case, an estimate of three starting values. The method being employed at present transforms the differential equations into integral equations and solves the resulting system by iteration. We have now completed the first iteration and it is hoped that the other iterations needed for convergence can be completed soon.

Plans for Future Research

The method devised for thrust prediction is being applied to other devices in an effort to shed some light on the anomalously high specific impulse measured in low density devices. Work will also continue on our calculations of the heat transfer in Co-axial Hall Current Accelerators.

Becasue the residence time in a plasma accelerator is usually small compared to the time required to reach equilibrium, use of the modified Saha's equation, as suggested by Kerrebrock instead of an appropriate rate equation, is subject to question. Calculations are being carried out at present to study the influence of ionization rate on discharge parameters.

Because of the influence of the Cathode Spot on specific impulse some thought will be devoted to this problem too.


Rotation Included
Experiment
r = 1.2
r = a+b/2
125
100
75
55
Isp, Sec.
3,000
6,000
9,000
B, Gauss
J = 200 Amps

References

1. Grossmann, W., Hess, R. V. and Hassan, H. A., "Experiments with a Co-axial Hall Current Plasma Accelerator", AIAA Paper No. 64-700, AIAA Fourth Electric Propulsion Conference, August 31 - September 2, 1964.

2. Hess, R. V., Feix, Marc R. and Hassan, H. A., "Excessive Ion Energies for Steady Discharges in Magnetic Fields", Paper P-11, 6th Annual Meeting, Division of Plasma Physics of APS. Nov. 4-7, 1964.

3. Hassan, H. A. et. al, "Experiments and Analysis for Co-axial Hall Current Accelerators and the Role of Ionization Effects", to be presented at the Sixth Symposium of the Engineering Aspects of MHD.

4. Grossmann, W., Hassan, H. A., Hess, R. V. and Oertel, G., "Nonequilibrium Ionization in Steady Discharges Crossed with Magnetic Fields", I. Experiments, II. Theory, APS Bulletin, Sec. II, Vol. 9, No. 3, p. 313, 1964.

5. Grossmann, W. "Theory and Experiment of a Co-axial Plasma Accelerator", Ph.D. Thesis, VPI, May 1964.